Growth of quantum wires for long-wavelength VCSEL with a polarized laser emission

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Abstract : We report continuous-wave operation at room temperature for a 1.55-µm VCSEL where the active region is made up of quantum-well. Now, self-organized quantum wires grown on InP substrate is used to obtain polarized laser emission.

1 Introduction

Vertical cavity surface emitting lasers (VCSELs) operating at 1.55-µm are very attractive laser sources for low-cost telecommunication systems, especially in emerging metro fiber-optic networks. Their circular, spectral, and spatial single-mode beam provides very efficient fiber coupling. They also offer other advantages like wafer testing before packaging or fabrication in array configuration. In contrast with edge-emitting laser, VCSEL presents polarization instabilities. This polarization instability is the result of circularly symmetric design of the VCSEL cavity. The difficulties encountered in controlling polarization under continuous-wave (CW) and dynamic operation are well known [1]. Several solutions have been carried out to solve this problem [2-4]. However, the use of an active region comprising self-organized nanostructures which show a gain anisotropy can be an interesting way to stabilize the polarization state of the VCSEL without adding processes in the VCSEL fabrication [5].
In this abstract, we report on the fabrication and the characterization of a VCSEL based on conventional quantum wells (QWs) active region. The device comprises two dielectric Bragg mirrors and it transferred on a silicon substrate to improve its thermal properties during the optical pumping. Recently, the growth of InAs quantum wires (QWires) on (0 0 1) InP substrate has been optimized. Anistropy properties of QWires have been measured with a photoluminescence experiment and suggest the possibilities to obtain VCSELs with a stable polarized laser emission.

2 Double Dielectric DBR VCSEL Fabrication

The low refractive index difference for the InP-based materials make the growth of efficient Bragg mirrors (DBR) very difficult. That is why epitaxial DBR have been replaced by dielectric Bragg mirrors. The dielectric materials used are amorphous silicon (a-Si) and amorphous silicon nitride (a-SiN_x) deposited with a magnetron sputtering system. An experimental reflectivity near 99.5% has been measured with a spectral bandwidth of 800 nm for a DBR with only 4.5 periods deposited on a glass substrate [6].

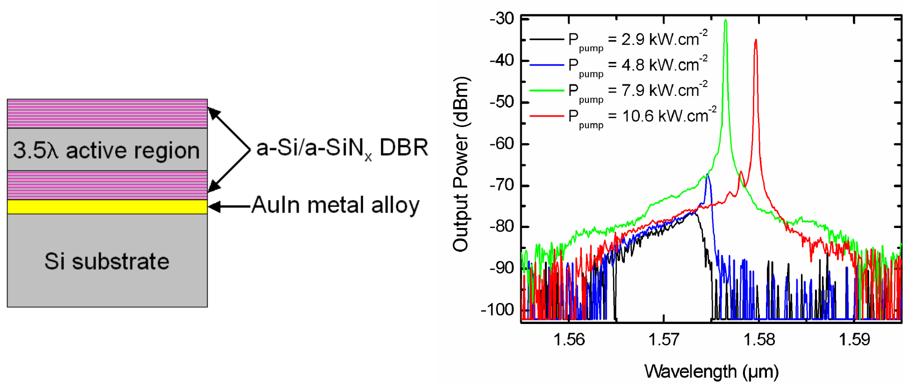

Fig.1 Left: Schematic cross-section of the studied VCSEL. Right: Emission spectra at room-temperature in continuous-wave operation for different pump powers.

The microcavity has a total length of 3.5λ. The active region, grown in MBE, is formed of three half-wave periods embedded between two InP layers. Each period of the active region contains a lattice matched package of two

InGaAs QWs and three GaInAsP barriers. A first a-Si/a-SiN_x Bragg mirror, of 6 periods is deposited on the active region. An Au-In bonding step was employed to transfer the sample on a silicon substrate. Mechanical polishing and selective etching are used to remove the InP substrate. As illustrated in Fig. 1, a second deposition of 6 periods of a-Si/a-SiN_x is realized to obtain the front mirror and our final device.

3 Characterization

The structure is optically pumped by a YAG laser at 1.064µm. The CW pump beam is focused on spot area of 200-μm^2. CW lasing operation up to 35°C has been obtained at 1.575-µm. Figure 2 shows the lasing spectra at room-temperature (RT) for various pump powers. The threshold power is close to 6 $kW.cm^{-2}$ at RT and the emission presents a full width at half maximum of less than 0.2-nm limited by the spectrometer resolution. The polarization state observed during theses characterizations was instable. As we can expect, the gain anisotropy for QWs is low and no polarization state can be established. Recently, the growth of InAs QWires on (0 0 1) InP substrate has been obtained under specific MBE growth conditions. AFM images reported in Fig. 2 shows the high quality of uncovered InAs QWires, with four embedded InAs QWires stacked layers separated by InGaAsP layers using the "double cap" procedure [7].

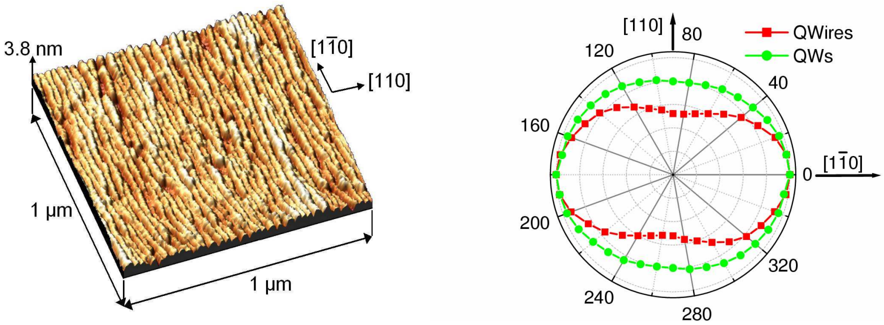

Fig. 2: Left: Atomic force microscopy images of InAs QWires grown on (0 0 1) InP substrate. Right: Polar plots of the polarized luminescence intensities of InAs QWires and InGaAS/InGaAsP QWs.

These self-assembled nanostructures have been characterized with a photoluminescence experiment and polarization state of QWires emission have been analyzed. As it is illustrated by the polar plot of PL intensity, the QWire luminescence efficiency is two times higher along the [1 –1 0] direction than for the [1 1 0] direction. The luminescence intensities is more sensitive to the analyzer orientation in the case of QWires than for InGaAs/InGaAsP QWs. The realization of a microcavity with an active region based on such nanostructures is studied to improve the polarization stability of the VCSEL.

4 Conclusion

The transfer of a device, comprising an InP-based active region and two dielectric DBR, on a silicon substrate allows to obtain a VCSEL with a laser emission in CW operation at RT. The study of QWires grown on (0 0 1) InP substrate revealed a gain anisotropy which is a promising solution to stabilize the polarization state of the VCSEL.

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